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PRIORITIZING RESEARCH AND DEVELOPMENT PROJECTS OF THE AIR FORCE HUMAN RESOURCES LABORATORY

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This study assessed the possibility of obtaining a reliable ranking of 12 research and development projects which could be used as a reference in allocating resources to those projects. Seven judges ranked the projects on six factors. Interjudge agreement in ranking the projects on an Overall Assessment (OA) factor was sufficiently reliable to indicate that project rankings can be used as a reference in allocating resources. Recommendations include having scientists prepare project descriptions in terms of the factors on which the projects are to be ranked; using different rating procedures for new projects than for older projects; ranking projects on an OA factor only; and keeping records of project rankings for several years so that ranking validities can be assessed.

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SUMMARY

The purpose of this study was to assess the possibility of obtaining an overall ranking of 12 AFHRL Advanced Technology Development Projects sufficiently reliable to be used as a reference document for fund allocations, manpower allocations, and program cuts. A second objective was to determine what criteria judges used in ranking the projects on overall merit.

Seven judges ranked the projects twice on six factors. The interjudge agreement in ranking the projects on an Overall Assessment (OA) factor for Session 1 was $r = .47$ ($p < .001$). For Session 2, $r = .60$ ($p < .001$). Eliminating a divergent judge increased the correlations to .57 and .69, respectively. Interjudge agreement increased across sessions ($p < .01$), presumably from the effects of feedback and changing one of the rating factors in Session 2.

The OA rankings for Session 1 did not differ significantly from those of Session 2 ($p = .50$). The rank-order correlation between the rankings for Sessions 1 and 2 was .97 ($p < .001$). Two additional judges who ranked the projects on only the OA factor gave rankings similar to those of the group, in half the time.

The factors most highly correlated with the OA factor were Customer Interest and Payoff to the Air Force. Cost, Schedule, and Technical Feasibility may not have been significantly correlated with OA because the Project Descriptions used by the judges did not adequately describe the projects in terms of the factors on which the projects were rated.

Recommendations include having project scientists prepare written descriptions of projects in terms of the factors on which the projects will be ranked; using different rating factors or procedures for new projects as opposed to older projects; ranking projects on an OA factor only; and keeping records of project rankings for several years so that ranking validities can be assessed. Interjudge rankings were sufficiently reliable to suggest that project rankings based on expected Program Payoff to the Air Force can be used as a reference in allocating research and development resources.

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PRIORITIZING RESEARCH AND DEVELOPMENT PROJECTS OF THE AIR FORCE HUMAN RESOURCES LABORATORY

I. INTRODUCTION

Research and Development (R&D) resources are often distributed to organizational units in the same proportion each year, based on historical precedent. Money and manpower are distributed proportionately, and little consideration is given to basing the allocation on new program priorities. While distributing resources proportionately is expedient, it ignores the fact that priorities change over time.

An alternative method of distributing resources is to base the allocation on program merit as assessed by a group of experts. In this study, seven judges ranked 12 AFHRL Advanced Technology Development Projects on six factors during two ranking sessions. The projects covered the areas of Personnel Selection and Classification, Technical Training, Flying Training, and Logistics. The objective of the study was to determine if it was possible to obtain an overall ranking of the 12 projects which was sufficiently reliable to be used as a reference document for fund allocations, manpower allocations, and program cuts. A secondary objective was to determine the basis on which the judges made their rankings. No attempt was made to establish the validity of the rankings.

Although AFHRL had previously used project rankings in distributing resources, the reliability and underlying rationale for the rankings was unknown. In this study, measures of rater reliability were obtained, and the rationale underlying the judges' rankings was examined. The rating factors employed were developed specifically for ranking Advanced Development Projects (6.3A), and were derived from recommendations from the judges used in this study and from other studies which assessed assigning priorities to R&D projects (Doherty & Seymour, 1983).

II. METHOD

Subjects and Design

Seven males volunteered to participate as judges. Three were from Headquarters, Human Systems Division (HQ HSD), and four were from AFHRL. Each judge held a position of responsibility at the headquarters level, either as a planner, programmer, or plans analyst. Six were civilians, grades GM/GS-13 and -14; one was an Air Force major. Four had doctorate degrees and three had masters degrees. All were familiar with the R&D projects through readings, briefings, and program management activities. Each judge ranked 12 R&D projects twice on six factors. The second ranking followed a feedback session held approximately 2 months after the first ranking session.

Materials

Each judge received a packet consisting of Instructions, Project Descriptions, Ranking Forms, and a Questionnaire. The Project Descriptions, formally called Descriptive Summaries, covered all AFHRL Advanced Development Projects in program elements 63106F, 63227F, and 63751F. Descriptive Summaries are documents prepared by AFHRL, HQ HSD, and HQ Air Force Systems Command (HQ AFSC), for use by Air Force management and the US Congress in allocating funds to R&D projects. All judges in the study were very familiar with the Descriptive Summaries and some even had a role in preparing them.

Each judge received six Ranking Forms stapled together. The order of the pages was counterbalanced across judges. Each form listed 12 projects and had one factor definition at the

top of the page. Project order was scrambled so that each judge had a different project ordering on each page. Five rating factors were scrambled such that each judge had a different factor order across pages. The sixth factor, Overall Assessment (OA), was always the last factor on which the projects were ranked.

Procedure

A preliminary meeting was held with all seven judges. The purpose of the study was explained, and each judge was given a list of sample factor definitions. They were then asked to recommend 10 factors on which to rate the projects. The factors selected were very similar to those recommended by the judges, and were as follows:

1. FEASIBILITY OF SCHEDULE (FS): The R&D schedule is likely to be met without the use of additional unplanned resources.

2. TECHNICAL FEASIBILITY OF PLANS (TF): The R&D plans are technically feasible, well defined, easy to understand, and seem to call for a logical sequence of events.

3. CUSTOMER INTEREST AND INVOLVEMENT (CI): The customer is interested in, and actively involved in, the R&D planning and programming.

4. FEASIBILITY OF PRODUCT TRANSITION (FT): Product transition plans are realistic, practical, affordable, and likely to occur as planned.

5. REASONABLENESS OF COST (RC): R&D cost is reasonable and affordable considering the expected payoff to the Air Force.

6. OVERALL ASSESSMENT (OA): All factors considered, rank the projects from highest (1) to lowest (12) priority.

Session 1: Two weeks after the preliminary meeting, all judges were mailed the Instructions, the Project Descriptions, the Rating Forms, and the Questionnaire. They were instructed to read the Project Descriptions and then rank the projects on each of the six factors selected by the authors. Rankings were to be based on Project Descriptions plus any other personal information the judges had from briefings and other readings. Judges were asked to return all forms within 7 days of receipt.

Session 2: Approximately 2 months after the due date, five of the judges ranked the projects again, after attending a 90-minute meeting during which they were given the results of their previous rankings. Each judge was shown every other judge's OA ranking for the 12 projects, plus the average of those rankings for each project. Discussion centered on the rationale for the rankings assigned and the definition of the factors.

As a result of the judges' recommendations, one rating factor was added and one was deleted for the second ranking session. "Payoff to the Air Force" (PO) was added, and "Feasibility of Schedule" (FS) was deleted. "Payoff to the Air Force" was defined as "Potential of the R&D product to increase the efficiency and effectiveness of Air Force operations." The factors were defined precisely, so that each judge would have the same framework for ranking during Session 2.

The two judges who were unable to attend the group session attended individual 30-minute feedback sessions with the primary author a few days following the group meeting. Thus, all

judges attended a feedback session prior to Session 2. This procedure could be viewed as a modified Delphi technique (Dalkey, 1969). No attempt was made to achieve a group ranking consensus.

III. RESULTS

Analysis of Overall Assessment (OA) Ranks: Table 1 shows the OA ranks judges assigned to the projects during each ranking session. The Kendall Coefficient of Concordance (Siegel, 1956) gave an average interjudge correlation of $r = .47$, $\chi^2(11, N = 7) = 41.81$, $p < .001$ for Session 1, and $r = .60$, $\chi^2(11, N = 7) = 50.25$, $p < .001$ for Session 2. Agreement among judges during both sessions was moderately high.

A comparison of the average pairwise Pearson correlations among the OA rankings of the seven judges across sessions (Table 2) shows higher intercorrelations during Session 2 than Session 1. Applying the Sign test, the probability of this difference being due to chance is $p = .008$ (one-tailed). The expectation was that there would be greater interjudge agreement following feedback, and there was. The change in one rating factor from Session 1 to Session 2 may also have contributed to the increase in interjudge agreement.

An analysis was also performed to see if there were any divergent raters. Judge 3 was divergent because none of his OA rankings was significantly correlated ($\alpha = .05$) with any other judge's rankings in either Session 1 or Session 2. Dropping Judge 3 from the analysis raised the Session 1 average intercorrelation among judges from .47 to .57, and the Session 2 average intercorrelation from .60 to .69.

The correlation between the average Session 1 and the average Session 2 OA ranks (Table 1, last two columns) was $r(10) = .97$, $t = 13.08$, $p < .001$, indicating high similarity between ranks across sessions, despite the change of one rating factor and the group discussion. As can be seen in the last column of Table 1, seven projects had the same average rank in both sessions, and all but one of the remaining five projects changed by only one rank. Project 1 changed by two ranks; it was ranked 1 in Session 1, and 3 in Session 2. The correlation between all Session 1 ranks and all Session 2 ranks (84 pairs) was $r(82) = .92$, $t = 7.32$, $p < .001$, further indicating the similarity of the rankings between sessions. A Sign test applied to the change in average OA ranks (second from the last column of Table 1), gives $p = .50$, indicating no significant difference in average OA ranks across sessions.

Questionnaire Analysis: Principal findings from analysis of the seven completed Questionnaires were as follows:

1. Judges reported that the Project Descriptions (Descriptive Summaries) contained insufficient information regarding funding, product implementation, and technical aspects of the projects to be useful in ranking the projects. On a 6-point scale (1 = Adequate, 6 = Inadequate), they rated Project Descriptions as Inadequate (Mean (M) = 5.7) for use in performing the ranking task. As a consequence, they based their ratings primarily on personal familiarity with the projects ($M = 1.3$). Some judges said the Descriptive Summaries were also inadequate for the purpose for which they were originally intended (i.e., program justification).

2. The rating factors employed during Session 1 were judged to be midway ($M = 3.0$) between Very Appropriate (1) and Very Inappropriate (6). One factor was deleted and one was added, as described earlier.

3. The judges took an average of 2 hours to complete the rankings and Questionnaire. They found the ranking task to be about midway ($M = 3.1$) between Very Difficult (1) and Very Easy (6), and they were midway ($M = 4.1$) between Confident (1) and Not At All Confident (6) about their

Table 1. Overall (OA) Ranking, Sessions 1 and 2

Projects	Judges														Project rank	
	1		2		3		4		5		6		7		Average	
1	6[a]	6[b]	11	7	11	11	3	7	7	8	4	5	2	2	6.3	6.6	7	7
2	12	12	12	12	12	12	11	11	12	12	12	12	12	12	11.9	11.9	12	12
3	10	10	6	6	5	6	1	4	2	3	7	7	3	3	4.9	5.6	4	5
4	1	1	4	5	2	2	7	3	5	2	5	3	1	1	3.6	2.4	2	1
5	9	9	7	9	3	1	9	9	9	9	9	9	10	10	8.0	8.0	9	9
6	3	3	1	2	6	4	5	2	6	4	1	1	4	4	3.7	2.9	3	2
7	4	4	3	1	8	8	4	5	4	5	8	8	7	7	5.4	5.4	5	4
8	11	11	5	8	4	5	8	8	3	6	3	4	11	11	6.4	7.6	8	8
9	2	2	2	3	9	7	2	1	1	1	2	2	5	5	3.3	3.0	1	3
10	7	7	9	11	10	10	12	12	10	11	11	11	9	9	9.7	10.1	11	11
11	8	8	8	4	7	9	10	10	11	10	10	10	8	8	8.9	8.4	10	10
12	5	5	10	10	1	3	6	6	8	7	6	6	6	6	6.0	6.1	6	6

[a]Session 1.
[b]Session 2.

rankings. They reported they were Quite Familiar (1) with the R&D projects (M = 2.0). Four of the seven judges believed that the rankings from the study should be used in making fund distributions, funding cuts, and manpower allocations. Five projects were recommended for termination and six were recommended for increased support. For two of these projects, the recommendations overlapped; that is, some judges recommended termination and others recommended increased support. Three projects received no specific recommendation.

Table 2. Average Pairwise Intercorrelations on OA Factor

Judges	Session 1	Session 2
1	.45	.60
2	.49	.54
3	.21	.35
4	.52	.73
5	.55	.71
6	.56	.66
7	.49	.57
8[a]	.53	.52
9[a]	.38	.35

[a]Evaluations completed following the study, with two judges ranking on the OA factor only (see DISCUSSION).

Analysis of the Relationships Among Factors: Tables 3 and 4 show the average rankings of the seven judges for all projects and factors for both sessions. Separate multiple regression analyses were performed on these rankings to determine the relationship between the OA rankings and the rankings on the five other factors. For Session 1, R (11) = .98, F = 24.74, $p < .001$. For Session 2, it was also .98 [R (11) = .98, F = 30.63, $p < .001$]. A stepwise regression analysis selected Customer Interest (CI) as the factor most highly correlated with OA for Session 1 [r (11) = .91, F = 46.83, $p < .001$], and Payoff to the Air Force (PO) and Feasibility of Product Transition (FT) as the most highly correlated factors for Session 2 [R (11) = .97, F = 44.23, $p < .001$]. Without entering the FT factor, the correlation between PO and OA was r (11) = .96, F = 85.92, $p < .001$. Thus, CI and PO were primary predictors of OA, perhaps because the judges had inadequate information about cost, schedule, and the other factors, so that it was necessary to rank on more global factors.

Table 3. Mean Ranks, Session 1

	Factors					
Projects	RC	FI	FT	CI	FS	OA
1	5.9	3.3	6.3	6.2	5.9	6.3
2	12.0	6.4	8.7	11.7	6.0	11.9
3	6.4	6.6	1.6	5.8	2.4	4.9
4	6.0	6.3	5.7	5.8	8.0	3.6
5	6.1	8.3	9.4	8.0	9.4	8.0
6	3.5	3.9	3.7	2.2	1.9	3.7
7	5.9	5.9	6.1	3.5	7.3	5.4
8	7.1	6.7	7.1	5.3	6.3	6.4
9	4.2	4.3	5.1	2.5	5.7	3.3
10	7.1	9.4	8.9	9.7	8.6	9.7
11	9.0	9.7	8.4	10.0	10.0	8.9
12	4.9	7.3	6.9	7.0	6.6	6.0

Table 4. Mean Ranks, Session 2

Projects	Factors					
	RC	FI	FT	CI	PO	OA
1	4.4	3.3	6.6	6.1	7.6	6.6
2	12.0	7.0	8.6	11.3	11.9	11.9
3	6.3	7.3	2.1	5.6	4.7	5.6
4	5.3	6.7	5.6	6.4	2.1	2.4
5	6.7	8.7	9.6	7.7	6.3	8.0
6	2.9	3.1	2.9	1.7	3.7	2.9
7	5.1	5.1	6.7	3.9	4.7	5.4
8	7.1	7.3	7.0	5.1	7.1	7.6
9	4.3	4.6	5.0	2.4	3.7	3.0
10	8.9	10.0	9.0	10.1	10.6	10.1
11	8.3	8.4	6.9	10.0	9.3	8.4
12	6.4	6.4	6.6	7.7	6.4	6.1

IV. DISCUSSION

The principal finding is that there was sufficient interjudge agreement to conclude that project rankings can be used as a reliable reference in allocating R&D resources. The fact that the Project Descriptions contained insufficient detail, and judges reverted to prior knowledge in making their evaluations, indicates that Project Descriptions should be tailor-made when used as a reference in ranking projects. They should be tailored to include the merits of the projects in terms of the factors on which the projects are to be evaluated. Describing the projects in terms of these factors may eliminate some of the judging bias which can result from prior knowledge. Some prior knowledge in this study seemed to be based on hearsay rather than personal knowledge of the technical merits of the projects. Project Descriptions should be prepared in a common format by project scientists. Using a common format may eliminate some of the bias introduced by different writing styles.

Interjudge agreement on the OA rankings increased from Session 1 to Session 2, but there was not a significant difference between average OA ranks across sessions. However, the project ranked 1 in Session 1 was ranked 3 in Session 2, which is an important change. Changes like this, plus the fact that interjudge reliability increased following the feedback session, indicate that feedback had an important effect. The total effect of the feedback is undetermined. Dalkey (1969) has found that face-to-face discussions, like the one in this study, tend to make group estimates less accurate than those following anonymous controlled feedback. Our impression was that the face-to-face discussion was beneficial, because it allowed judges to share information and possibly make more knowledgeable judgments. Dalkey's task was very different from the one performed in this study. His subjects estimated known facts of the sort found in an almanac, such as "How many telephones were in use in Africa in 1965?" Very likely the effects of feedback are related to the nature of the subjects' task.

Based on comments made during the feedback session, it may be wise to use different ranking factors for new versus older projects. It is, for example, more difficult to make judgments about cost, schedule, and technical risk for new projects than for projects which have been underway for 2 or 3 years. In fact, it may be appropriate to use an entirely different resource allocation procedure for new projects. Small amounts of seed money could be provided for several new projects, rather than large amounts of money for a few highly ranked projects. This risk

averaging technique may be the best course of action in cases of high uncertainty. As the projects mature, a ranking procedure could be adopted.

Similar OA rankings might have been obtained without having the judges first rank the projects on the other five factors. This notion was tested by having two additional judges rank the projects only on OA. They were told to rank the projects on Overall Payoff to the Air Force, considering Reasonableness of Cost, Feasibility of Schedule, Customer Interest and Involvement, Technical Feasibility of Plans, and Feasibility of Product Transition. They ranked the projects once, and then again after seeing the OA ranks for all judges in Session 1; there was no feedback session. One judge's ranks correlated r (10) = .52, t = 1.91, p > .05, (two-tail) with average Session 1 ranks, and r (10) = .50, t = 1.84, p > .05 with average Session 2 ranks. The second judge's ranks correlated r (10) = .72, t = 3.28, p < .01 for Session 1, and r (10) = .66, t = 2.76, p < .05 for Session 2. There was little or no difference between their first and second set of ranks. One judge made two rank-order changes from Session 1 to Session 2; the other made none. The pairwise correlations of these judges' ranks with the seven other judges' ranks, shown in Table 2 for judges 8 and 9, are at the lower end of the range of correlations. The merits of the shorter procedure may be worthy of further investigation, however, assuming only an overall ranking is desired. Present results are inconclusive.

The major unknown factor in this study is the validity of the rankings. The divergent judge may have been right, the group may have been right, or both may have been wrong about the expected payoff of the projects. To assess the merit of the rankings, it would be necessary to initiate a longitudinal study, ranking the projects periodically, and keeping a record of those rankings so that the relationship between the rankings and eventual project payoff could be determined.

V. CONCLUSIONS/RECOMMENDATIONS

1. Interjudge rankings were sufficiently reliable to suggest that rankings based on estimated project payoff to the Air Force can be used as a reliable reference in distributing R&D resources.

2. The feedback session allowed judges to share information about project merits and their proposed ranks, and increased interjudge reliability.

3. For Session 1, Customer Interest was the factor most highly correlated with the overall rankings. For Session 2, it was Payoff to the Air Force.

4. Project Descriptions should depict the projects in terms of the factors on which the projects are being evaluated. Project scientists should prepare the Project Descriptions in a standard format.

5. If only an overall ranking is desired, only one overall ranking may be necessary, rather than rankings on several related factors and then on an overall factor.

6. Different ranking factors should be used for new versus old projects. Alternatively, small amounts of seed money might be provided for several new projects, rather than large amounts of money for a few highly ranked projects, thereby averaging the risks. Projects would be ranked after being underway for at least 1 year.

7. Projects should be ranked twice annually for at least 5 years, so that the relationship between ranks and eventual project payoff can be determined.

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